A Comparison between four-tier framework and three-tier framework for online applications of 3D GIS visualization

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Abstract: Online application of 3D visualization for GIS (Geographic Information System) data is of interest to not only professionals such as cartographers, geographers, geologists and psychologists but also popular among the ordinary people. The system's conventional design is generated from client/server based architecture. This architecture is the main platform for designing the online system architecture, which works based on the distributing concept which is "tier". The tier is required to separate the works/tasks between the system architecture. Currently, three-tiers architecture is the most well-known architecture used in GIS applications and other application. However, this architecture has a drawback on the middle tier which needs more processing power to meet the request from multiple of users. GIS applications, especially which involve 3D visualization generate a massive amount of data. Due to this situation, the use of the current three-tier framework for online application of 3D visualization for GIS will decrease the performance of the system in terms of time for processing the request from the users. The aim of this study is to introduce the new four-tier framework and compare it with the existing three-tier framework. This framework consist of four-tier architecture, which is divided into client tier, logic tier, visualization process tier, and database tier. The comparison is based on response time, loading time, frames rate per second, CPU usage, and memory usage. The new framework shows superiority in its performance, and the processing power is reduced.
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1. Introduction

The process of exploring, transforming, and viewing the data as images is known as visualization where the understanding and insight into the data could be achieved (Schroeder, Martin, & Lorensen, 1998). Visualization can be divided into 2D, 3D and currently 4D visualizations. The 2D visualization renders the objects in two dimensions (2D) while 3D visualization renders the objects in three dimensions (3D). Nowadays, most of the systems still maintain the 2D visualizations but lack on fully functionalised 3D visualizations, especially in GIS communities. The trend currently is moving towards using the Internet platform to visualize the information. This platform enables people to interact and share information more efficiently. It received attention in the early 1990s due to the development of standard visual tools on the web for exchange of information, such as Mosaic, Netscape Navigator, and Microsoft Explorer. Because of this, the number of Internet users and its technology has increased dramatically, for example, in 2009, the numbers of Internet users are rapidly increasing, especially in the rural areas, of about 4 million in Malaysia. Therefore, in 2005, the new generation of geo-browsers such as Google Earth, Microsoft Virtual Earth and NASA's World Wind have emerged for users daily work and decision making purposes (Sipes, 2007). Furthermore, this technology allows an opportunity to perform mix client/server visualization. Most of the system architecture for WWW is developed based on client/server architecture (Islam, Sayeed, & Samraj, 2008; Nasir, Hamid, & Hassan, 2009; Talhi, Djoudi, & Batouche, 2006; Wang, Zhou, & Li, 2012,

Saba et al., 2012; Rehman and Saba, 2013). This architecture is the main framework for designing online system, whereby it is based on the distributing concept known as "tier".

Three-tier framework is the most well-known architecture used in GIS applications but it has disadvantages on the middle server which needs more processing power to manage a huge data, especially the GIS system. Therefore, the main objective of this study is to introduce a new four-tier framework for online application of 3D visualisation for GIS data in order to overcome the current impediments in the use of the three-tier frameworks. This framework is derived based on four-tier architecture of client/server architecture. The tiers are divided into client tier, logic tier, visualization process tier, and database tier. Each of the tiers has its own functions. However, each of the tiers also needs to interact with each other to process the request by the client. The result from this new framework is compared with the results from the three-tier framework. The new framework showed to be superior in performance. This framework is novel as it can help the users to visualize multitude of applications in online 3D environments with GIS capabilities.

2. Literature Review

Based on the literature survey, the used of four-tiers architecture is only designed for GIS application of visualization in 2D and not for 3D (Luqun, Jian, & Yu, 2002; Luqun & Minglu, 2004, Saba and Rehman, 2012; Saba and Alqahtani, 2013). The current use of this framework is mainly for 2D visualization and not related to the GIS applications. For example, in the health geographic, four-tier frameworks are designed for mapping and sharing the disease information. The product of this framework is only 2D maps, which can monitor the information of the disease without any GIS capabilities. The advantage of this system is that it can collaborate interactively among the partners (Gao, Mioc, Anton, Yi, & Coleman, 2008). Mahmoudi et al. (2010) had introduced interactive web based 2D and 3D medical image processing and visualization based on the four-tier frameworks. Their framework consists of algorithm tier, web-user-interface tier, server communication tier, and wrapper tier. VRML (Virtual Reality Markup Language) is used to visualize their images. However, this system was only tested in medical imaging but not for GIS purpose. The development of an efficient and reliable system with more than three-tiers is still an imprecise science, but research in distributed computing continues to increase the availability and usefulness of the system (Lewandowski, 1998).

Chartier (2001) defined tier as "any number of levels arranged above another, each serving distinct and separate task". It means that each tier has its own function, which is connecting to each other in separate levels for processing the request from the client. Tier can be divided into three types, which are one tier, two tier, and three-tier framework. One tier framework can be defined as the applications running on the single computer or isolated systems, which is disconnected from the network but can work correctly. Two-tier framework is normally formed by the server side software and client side software. When the web communication protocol is established, the data will be transmitted from server to the client. Then client software will display the data inside the client computer. However, this architecture had some disadvantages such as inability to accommodate, the users demand for system capacity (Luqun, et al., 2002), very hard to upgrade and extend (Luqun & Minglu, 2004), and lower performance when the online user is increased. Due to these defects, the three-tier framework has been introduced by adding one more tier in the middle between the server and client (Schussel, 1997). This tier has several functions such as queuing, application execution, logic interpretation, and database staging. The basic model of this framework is divided into three independents parts, which are the presentation tier, logic tier, and data tier. Many researchers have utilized this framework in various applications such as visitor information system (Varun, Tarun, Langan, & Praveen, 2004; Saba and Altameem, 2013), hurricane simulation (Chen, et al., 2003), managing disaster (Zhou, Liu, Fu, & Zhang, 2009), e-Learning systems (Abdul-Kader, 2011) and online 3D terrain visualization (Ruzinoor, Shariff, Mahmud, & Pradhan, 2011a, 2011b; Ruzinoor, Shariff, Mahmud, Pradhan, & Rahim, 2012).

3. Methodology

The complete framework comprises Web Server (Appache), Hypertext Pre processor (PHP), database (MySQL), and VRML. Each of these technologies has their own unique functions. For example, Web server act as the server which manage the communication between the data request by the users. It sends the data directly to the users based on their demand. All of these technologies were integrated together to develop the complete system framework. This new four-tier framework is implemented in oil palm plantation application with oil palm trees as 3D objects.

The framework consists of four-tiers, which are client, logic, visualization process, and database respectively. Figure 1 shows the architecture of this new four-tier framework. The detail discussion of the

functions for each tier in the framework is described in the next sections.

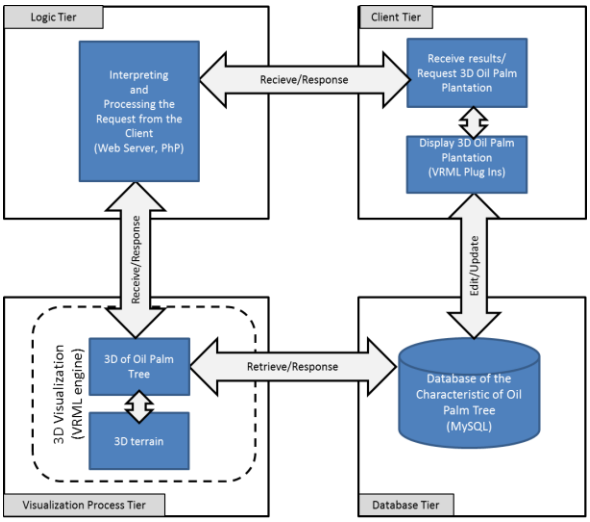

Figure 1 The architecture of a new four-tier framework

3.1 Client Tier

This tier consists of users' web browser based solution to visualize the data, which is in VRML standard. This is the standard of 3D world/object definition language design to be used in web-based applications. In this study, the visualized data is 3D terrain overlaid with satellite image and tree plantation. The tree plantation is separated into two parts, which are trunk with textured image and the leaf. The leaf colour can be edited. As mentioned earlier in database tier, the users can edit the location of the tree and the leaf colour by accessing the database of the system. Besides that, the advantage of VRML is that the users can interact with the system by flying through, walk through, jump, zoom in, zoom out, pan and slide. The user only needs to install the VRML viewer for accessing the data. There are many types of free VRML viewer available to download from the Internet. This kind of setup makes this system flexible.

3.2 Logic Tier

The Uni Server was used as a web server for processing the data and publish data on the website. This system uses Hypertext Pre processor (PHP) to establish a connection to a MySQL database for the database operations. PHP is usually written in HTML context for server-side scripting language, and it is open source and can be used on across platforms. The main advantage of PHP is an ability to support different types of databases such as MySQL, Oracle, Open Database Connectivity (ODBC) and Ingres (Basic & Nuantawee, 2004). In this case, MySQL is used as the database to update the data (coordinate and leaf colour) via the internet using the interface on the user's browser inside the client tier. To render the scene in 3D environments, the VRML scripts were used to manipulate the data. The headers of PHP need to be set to make PHP script understand the VRML scripts. The PROTO function was defined to hold the data of the tree. All the characteristic of the tree such as leaf colour and trunk with it textures are defined in this PROTO function. These functions are called at the end of PHP script. The looping function was used to read each attribute of the coordinate and leaf colour. The users can open the file with the PHP extension inside their browser. The users need to install VRML browsers as well to render the environment inside online 3D environment.

3.3 Visualization Process Tier

Visualization process tier comprises of two parts which is terrain visualization and the oil palm trees visualization in 3D. The terrain visualization involves 3D terrain data overlaid with higher resolution of satellite images. An intensive experiment has been conducted to find the best solution for representing the 3D terrain visualization. Based on the results from the experiment, the best terrain data was the DEM from LiDAR, and the best satellite image was QUICK BIRD (0.67 m resolution).

The other parts of visualization were generated from the tree plantation in 3D from the database. The objects of tree plantation were divided into two parts, which are trunk and the leaf. Both the data regarding to oil palm trees is stored in database tier. Each of the data belongs to single trees. The coordinates of the tree and also the colour of the leaf can be changed by the user through the client tier. Both visualizations produced a complete environment of the plantation in 3D web-based environments.

3.4 Database Tier

The database is important and needs to be designed properly for optimisation query and user friendly system (Mohd Rahim, Daman, & Selamat, 2004). The database tier in this framework used MySQL as the database for managing the characteristics of tree plantation data. The reason of using this database is because it is free and the most popular database among Internet developers due to its ease of usage. There are two parts of tree plantation stored in the database, which is the tree location and leaf colour. The location of the trees are stored as coordinates (x,y). This data can be edited by the user

according to the real location of trees inside the plantation. Meanwhile, the leaf colour is stored in RGB formats, which can also be edited according to the leaf colour. The advantage of this data are the users can set the tree with the disease in certain colour and the tree without the disease in green colour. When both data were edited by the user, the online system will automatically update the data and makes it available on the Internet. Plantation managers who need to monitor the latest update of the plantation like plant manager can access the system anywhere they like and at any time. The advantage of this framework is that the system can be visualized in 3D environments, which offers interactivity like flythrough and walkthrough inside the plantation. With this capability, it offers more information of the tree plantation compared to the 2D system.

4. Discussions

The results of this study are presented by comparing the new four-tier framework with the existing three-tier framework. Before the comparison can be made, both frameworks should be well functioning to run the system. The comparison is made to both frameworks by using the same data of the oil palm trees (3D objects) inside the plantation. For the comparison to be more effective, the oil palm plantation system is divided into four different sizes of oil palm plantation, which is 10, 30, 50, and 100 oil palm trees. Figure 2 shows the interface of oil palm plantation system with 100 trees.

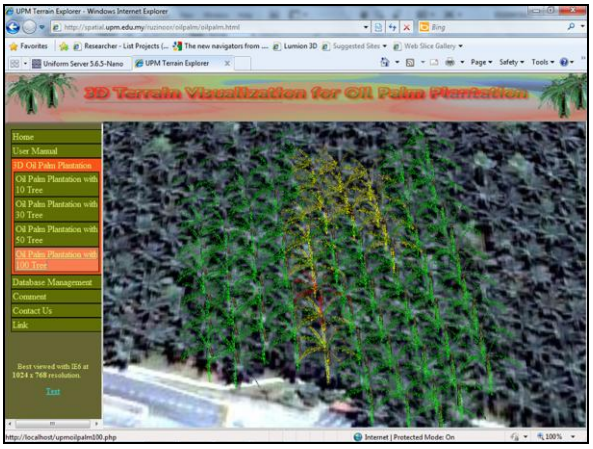

Figure 2 The interface of oil palm plantation system with 100 trees (3D objects).

The measurement for both frameworks is performed in an online environment. The measurement is performed by comparing the value of response time, loading time, frames per second, CPU usage, and memory usage. This technique is adopted from Sherif and Abdul-Kader (2011) which measure their system performance based on frame rate, upload time and visualization time. The percentages difference is calculated for each comparison criteria to indicated the performance of both frameworks. The calculation is performed by using formula:-

$$Percentage\ difference = \frac{max\ value - min\ value}{max\ value} X\ 100$$

The result of the comparison is discussed in the following sections.

4.1 Comparison on Response Time

The first comparison is made based on response time. The response time means that the time taken from the first byte of page requests sent until the last received byte of server response. The four-tier system frameworks stated the fastest response time of 0.021 s when the number of oil palm trees are 10. The slowest value of loading time is recorded at three-tier system framework with 0.272 s when the number of oil palm trees are 100. The gap between these two values is 0.251 s. Figure 3 shows the comparison of response time.

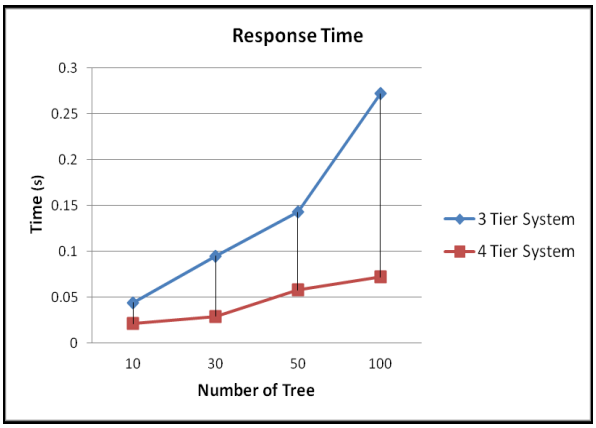

Figure 3 The response time graph for comparison of three and four-tier system framework

From Figure 3, it can recognize that from the whole value of response time recorded, the gap between two lines is not stable especially when the number of oil palm trees become 30. However, the rest of the values gradually increase with the increase of the number of oil palm trees. When the number of oil palm trees become 100, there is a marked difference between the two lines. Therefore, it can be concluded that the four-tier system framework is better because it has highest percentage differences of

response time which is 62% average compared to the three-tier system framework.

4.2 Comparison on Loading Time

The second comparison is made based on loading time. The loading time means the time of getting the content of server response, which is from the moment a request is sent until the moment a response is received. The four-tier system frameworks recorded the shortest loading time of 2.65s when the number of oil palm trees are 10. The longest value of loading time is recorded at three-tier system framework when the number of oil palm trees are 10. The gap between these values is 16.16 s. Figure 4 shows the results of loading time.

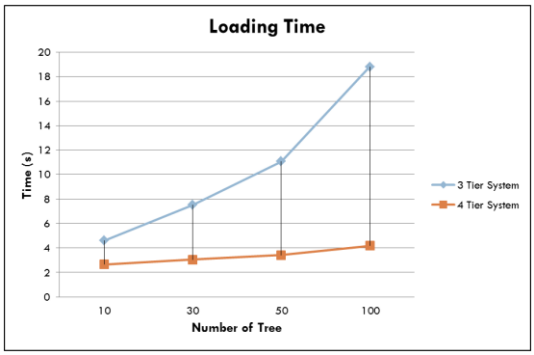

Figure 4 The loading time graph for comparison of three and four-tier system framework

From Figure 4, it can recognize that from the whole value of loading time recorded, the gap between two lines has increased tremendously with the increasing number of oil palm trees. However, when the number of oil palm trees reached 100, the difference between two lines is maximum. Therefore, it can be said that the four-tier system framework is better because it has highest percentage differences of loading time which is 64% average compare to the three-tier system framework.

4.3 Comparison on Frames Per Second

The third comparison is made based on frames per second. Frames per second (fps) can be defined as the measurement of how much information is used to display the motion generated from the quick succession of frames. The motions appear smoother when the fps value is higher. The four-tier system frameworks recorded the highest value of fps with 52 fps when the number of oil palm trees are 10. The slowest value of fps is recorded at three-tier system framework with 18 fps when the number of oil palm tree is 100. The gaps between these values are moderate, which is 34 fps. Figure 5 shows the results of frames per second (fps).

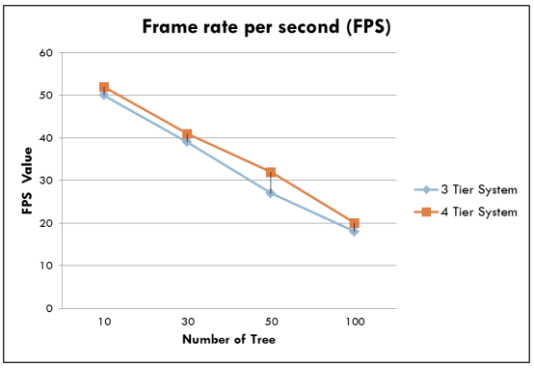

Figure 5 The frames per second (fps) graph for comparison of three and four-tier system framework

From Figure 5, it can be seen that the difference between the two lines is stable for about 2 fps when the number of oil palm trees at 10, 30, and 100. But when the number of oil palm tree is 50, the difference between two lines is noticeable. This may due to the network bandwidth and queuing process (read and write) is at the best situation during the time was tested. Therefore, it can be concluded that the four-tier system framework is better because it has highest percentage differences of fps value which is 9% average compare to the three-tier system framework.

4.4 Comparison on CPU Usage

The fourth comparison is made based on CPU usage. The CPU usage means the amount of work that CPU needs for processing instruction of computer programs out of 100%. The four-tier system framework shows the lowest percentage for CPU usage with only 6% when the number of oil palm trees are 10. This is good because it has sped up and smoothen the online 3D visualization system. The highest percentage value of CPU usage at three-tier system framework is 29% when the number of oil palm trees are 100. This is not good because it has slowed the rendering time of the online 3D visualization system. The gaps between the lowest and highest value is only 23%. Figure 6 shows the results of CPU Usage.

From Figure 6, it can be observed that the gap between three-tier and four-tier system framework is consistent within 5% starting from 10 oil palm trees until 100 oil palm trees. However, when the number of oil palm tree is 30, the difference between the two lines is shortest. This may due to the network bandwidth and queuing process (read and write) is at

the best situation during the time was tested. Therefore, the four-tier system framework is better because it has less CPU usage with lowest percentage differences which is 29% average compare to the three-tier system framework.

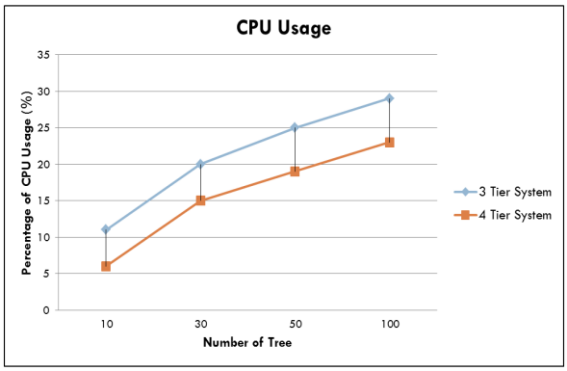

Figure 6 The CPU usage graph for comparison of three and four-tier system framework

4.5 Comparison on Memory Usage

The fifth comparison is made based on memory usage. Four-tier system frameworks shows the lowest value for memory usage with only 1.03 Gb when the number of oil palm trees are 10. This is good because it has sped up and smoothen the online 3D visualization system. The highest value of memory usage is recorded at three-tier system framework with 1.37Gb when the number of oil palm trees are 100. This has slowed the rendering time of online 3D visualization system. The gaps between lowest and highest value is 0.34Gb. Figure 7 shows the results of memory usage.

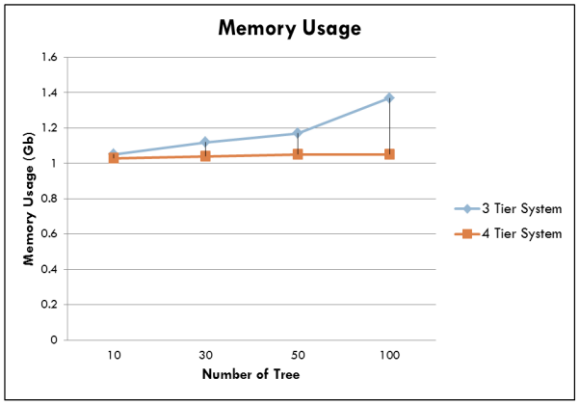

Figure 7 The memory usage graph for comparison of three and four-tier system framework

From Figure 7, it can be seen that the gaps between three-tier and four-tier system framework increased almost double from 10 to 100 oil palm trees. However, when the number of oil palm trees are 100, the difference between the two lines is at its maximum. The four-tier system framework is better because it has less memory usage with lowest percentage differences which is 11% average compared to the three-tier system framework.

5. Conclusion

In conclusion, based on the comparison results between the three-tier and the new four-tier framework, the performance of the four-tier framework is superior with highest percentage differences about 35% average of all tested being done. Almost all the four-tier framework's result are better in terms of loading time, response time, frame per second, CPU usage, and memory usage. These mean that the new architecture of online 3D application based on four-tier framework helps to reduce processing power in the middle tier to process 3D visualization data. Its performance in an online environment also increased tremendously. The four-tier framework has a high potential to be formalized into other online applications of 3D visualization such as determination of interesting tourism spots, visualization of hazardous terrain and a host of other applications.

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References

1. Abdul-Kader, H. (2011). e-Learning Systems in Virtual Environment. *The International Arab Journal of Information Technology*, *8*(1), 23-29.
2. Basic, F., & Nuantawee, M. (2004). Generating a VRML World from Database Contents: Illustrated by Application to Flood Risk Communication. *Journal of Spatial Science*, *49*(1), 37-47.

3. Chartier, R. (2001). 15 Seconds: Application Architecture: An N-Tier Approach - Part I. Retrieved 1 February, 2011, from http://mediakit.internet.com/icom_cgi/print/print.cgi?url=http://www.15seconds.com/issue/011023.htm
4. Chen, S. C., Gulatit, S., Hamid, S., Huang, X., Luo, L., Morisseau-Leroy, N., et al. (2003, Aug. 11-13, 2003). *A three-tier system architecture design and development for hurricane occurrence simulation.* Paper presented at the International Conference on Information Technology: Research and Education (ITRE2003), Neward, NJ, USA.
5. Gao, S., Mioc, D., Anton, F., Yi, X., & Coleman, D. J. (2008). Online GIS services for mapping and sharing disease information. *International Journal of Health Geographics*, *7*(8).
6. Islam, M. R., Sayeed, M. S., & Samraj, A. (2008). A Secured Fingerprint Authentication System. *Journal of Applied Sciences*, *8*(17), 2939-2948.
7. Lewandowski, S. M. (1998). Frameworks for component-based client/server computing. *ACM Computing Surveys*, *30*(1), 3-27.
8. Luqun, L., Jian, L., & Yu, T. (2002, July 9-12, 2002). *The Study on Web GIS Architecture Based on JNLP*. Paper presented at the The ISPRS Technical Commission IV Symposium, Ottawa, Canada.
9. Luqun, L., & Minglu, L. (2004). A Research on Development of mobile GIS architecture *Environmental Informatics Archives*, *2*(2004), 920-926.
10. Mahmoudi, S. E., Akhondi-Asl, A., Rahmani, R., Faghih-Roohi, S., Taimouri, V., Sabouri, A., et al. (2010). Web-based interactive 2D/3D medical image processing and visualization software. *Computer Methods and Programs in Biomedicine*, *98*(2), 172-182.
11. Mohd Rahim, M. S., Daman, D., & Selamat, H. (2004). Design and Impelementation of Double Cube Data Model for Geographical Information System. *The International Arab Journal of Information Technology*, *1*(2), 215-220.
12. Nasir, M. H. N. M., Hamid, S. H., & Hassan, H. (2009). WebML and .NET Architecture for Developing Students Appointment Management System. *Journal of Applied Sciences*, *9*(8), 1432-1440.
13. Rehman, A. and Saba, T. (2013). An intelligent model for visual scene analysis and compression. *International Arab Journal of Information Technology*, 10(2), 126-136 .
14. Ruzinoor, C. M., Shariff, A. R. M., Mahmud, A. R., & Pradhan, B. (2011a). Online 3D Terrain Visualization of GIS Data: A Comparison between Three Different Web Servers. *Pertanika Journal of Science and Technology*, *19*(S), 31-39.
15. Ruzinoor, C. M., Shariff, A. R. M., Mahmud, A. R., & Pradhan, B. (2011b). Online 3D Terrain Visualization: Implementation and Testing. *Journal of Applied Sciences*, *11*(18), 3247-3257.
16. Ruzinoor, C. M., Shariff, A. R. M., Mahmud, A. R., Pradhan, B., & Rahim, M. S. M. (2012). An effective visualization and comparison of online terrain draped with multi-sensor satellite images. *Arabian Journal of Geosciences*, *in press*, 1-9.
17. Saba, T. Alzorani, S. Rehman, A. (2012) Expert system for offline clinical guidance and treatment, *Life Science Journal*, ;9(4): 2639 -2658.
18. Saba, T. and Rehman, A. (2012). Effects of Artificially Intelligent Tools on Pattern Recognition, *International Journal of Machine Learning and Cybernetics*, vol. 4, pp. 155-162.
19. Saba, T. and Alqahtani, F.A. (2013) Semantic Analysis Based Forms Information Retrieval and Classification, *3 D Research*, vol. 4(4).
20. Saba, T. and Altameem, A. (2013) Analysis of Vision based Systems to Detect Real Time Goal Events in Soccer Videos, *Applied Artificial Intelligence*, 27(7), 656-667.
21. Schroeder, W., Martin, K., & Lorensen, B. (1998). *The Visualization Toolkit 2nd edition*. New Jersey: Prentice Hall.
22. Schussel, G. (1997). Client/Server: Past, Present and Future. Retrieved 21 July, 2011, from http://www.dciexpo.com/geos/dbsejava.htm
23. Sherif, M., & Abdul-Kader, H. (2011). Novel Robust Multilevel 3D Visualization Technique for Web Based GIS. *The International Arab Journal of Information Technology*, *8*(1), 59-65.
24. Sipes, J. L. (2007, 1 May 2007). 3D Photorealistic Modeling Using Geobrowsers (Spatial Tech column). Retrieved 10 October, 2011, from http://gis.cadalyst.com/gis/GIS/3D-Photorealistic-Modeling-Using-Geobrowsers-Spati/ArticleStandard/Article/detail/424087
25. Talhi, S., Djoudi, M., & Batouche, M. (2006). Authoring Groupware For Intelligent Tutoring Systems. *Information Technology Journal*, *5*(5), 860-867.
26. Varun, S., Tarun, S., Langan, D., & Praveen, K. (2004, Oct. 3-6, 2004). *A framework for Internet GIS based computerized visitor information system for theme parks.* Paper presented at the The 7th International IEEE Conference on Intelligent Transportation Systems, Washington DC.
27. Wang, X., Zhou, B., & Li, W. (2012). A Streaming Protocol for Memcached. *Information Technology Journal*, *11*(12), 1776-1780.
28. Zhou, Y.-x., Liu, G.-j., Fu, E.-j., & Zhang, K.-f. (2009). An object-relational prototype of GIS-based disaster database. *Procedia Earth and Planetary Science*, *1*(1), 1060-1066.